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Acoustic Analysis of Small Arms Fire

by

Scott Peterson
Paul Schomer

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This report presents the results of a study of the spectral content of small arms fire at varying distances. These data can be used in the design of noise mitigating structures for small arms ranges. The one-third octave spectra of both the bow wave and muzzle blast, for distances ranging from 162 to 577 m from the source are presented. The data are then used to develop a model that predicts the relative levels of the two components over much larger distances. This leads to the finding that, along the line where the bow wave is maximum, the bow wave predominates over the muzzle blast by a few dB for distances as large as 10 km. In other directions, the muzzle blast predominates.

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This report presents the results of a study of the spectral content of small arms fire at varying distances. These data can be used in the design of noise mitigating structures for small arms ranges. The one-third octave spectra of both the bow wave and muzzle blast, for distances ranging from 162 to 577 m from the source are presented. The data are then used to develop a model that predicts the relative levels of the two components over much larger distances. This leads to the finding that, along the line where the bow wave is maximum, the bow wave predominates over the muzzle blast by a few dB for distances as large as 10 km. In other directions, the muzzle blast predominates.

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FOREWORD

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FIGURES

ACOUSTICS ANALYSIS OF SMALL ARMS FIRE

1   INTRODUCTION

Background

Small arms can be an environmental noise problem for people living and working either both on- or off-base in the vicinity of a firing range. This is especially true when the small arms complex is associated with a reserve or guard component or is not associated with a larger range complex where large weapons are fired. In the absence of large weapons, the small arms become the predominant noise source, the range complex is smaller, and communities are situated closer to the range. In Germany this is frequently the case. Small arms firing is associated with a local Kaserne (German military station) and National Guard weekend and local training sites where no large weapons are fired and the distance to on- or off-post housing can be very small, sometimes less than 100 meters (m).

The noise generated at a small-arms range has two components: the muzzle blast and the sonic boom, bow wave noise generated by the flight of the bullet. The bow wave only propagates forward of the line-of-fire and within the mach angle defined by the bullet's speed. Because the bow wave has been reported as a major noise source in Germany, military designers need accurate small arms sound generating data when designing noise mitigating structures for small arms ranges.

Objective

The purpose of this research was to document measurements and analysis of the muzzle blast and bow wave sound generated by small arms (M16) fire and to estimate where in the vicinity of a firing range either sound will predominate.

Approach

Researchers gathered experimental data for the M16 rifle at a flat, open test range at Aberdeen Proving Ground, MD. The data were analyzed to obtain one-third octave sound spectra for the two components of a shot (muzzle blast and the bullet shock wave), the overall sound exposure level (SEL), and the SEL for each component of a gun shot. The data were taken at eight stations to allow for the analysis of the decay rate with distance. The results for each component were compared to determine the dominant factors in small arms fire. The results were modeled to account for geometric spreading, air absorption, and source directivity and were then extrapolated to determine the expected results for distances longer than those tested.

Mode of Technology Transfer

The U.S. Army Environmental Hygiene Agency (USAEHA) has the operational mission to assist Army installations with noise assessment and mitigation. USAEHA will use the data in this report in assessing small arms noise around military installations. These data will also be used to develop noise mitigating structures as required, primarily in Germany. Headquarters, U.S. Army Europe and Seventh Army will supply these data to the European Division, which will provide them as "Government Furnished Materials" for a contract to design a noise mitigating structure for a small arms range; however, no specific range upgrades or modifications are currently planned. In the continental United States, USAEHA will supply these data if noise mitigating structures are recommended at a small arms range.

2 PROBLEM DESCRIPTION

When small arms are fired, the sound created has two major components: the muzzle blast and the bow shock or bow wave. The muzzle blast is caused by the powder charge exploding in the gun chamber and can be modeled as an explosion of some equivalent weight of TNT with some directivity specific to the weapon being fired. Therefore, except for the nonuniform directivity pattern, which will be discussed later, the muzzle blast can be modeled by a simple point source located at the point of fire. This leads to the conclusion that the muzzle blast should propagate in a spherical pattern. Sound exposure level (SEL) is used to measure this pattern and is defined by:

$$SEL = 10 \log_{10} \frac{\int p^2 dt}{p_0^2 t_0} \qquad \text{[Eq 1]}$$

where:

p_0 = 20 μPa,
t_0 = 1 second,
the integral is performed over the entire event.

Considering that the energy decays in proportion to the surface area of a sphere, it can be shown that the SEL decays, purely due to geometric spreading, as R^{-2}, where R is the distance from the point of fire to the point of interest. This is equivalent to -6 decibel (dB) per doubling of distance.

The *bow wave portion of the shot noise* is caused by the bullet traveling faster than the speed of sound. As long as the bullet's mach number exceeds 1, a bow wave will be continually produced along the bullet's trajectory. The amplitude of this bow wave depends on the geometry and caliber of the bullet, while the direction of propagation relative to the trajectory is determined by the speed of the projectile. As shown in Figure 1, a supersonic bullet causes a bow wave with a mach angle alpha (α). The bow wave propagates perpendicular to the mach angle, creating a conical spreading pattern (Figure 2). It has been shown that the SEL of the bow wave portion of the gunshot depends on the surface area of this conical shape (Thompson). The SEL decays nonlinearly in the near field, where the pressure is very large. This nonlinear model (Pierce 1989) suggests that the SEL decays in direct proportion to $h^{-3/4}$, where h is the horizontal distance from the bullet trajectory to the point of interest. The distance the bow wave has traveled perpendicular to the mach angle is related to h by

$$r = h \cos(\alpha) \qquad \text{[Eq 2]}$$

Consequently, r is directly proportional to h and the SEL decays in the near field in direct proportion to $r^{-3/4}$. This can be stated as -4.5 dB per doubling of distance r. In the far field, and for smaller peak pressures, the SEL decay can be modeled by a linear model that depends solely on the geometrical spreading effects of the conical surface. When this is the case, the *SEL decays in proportion to* $r^{-1/2}$, *which is* equivalent to -3 dB per doubling of distance.
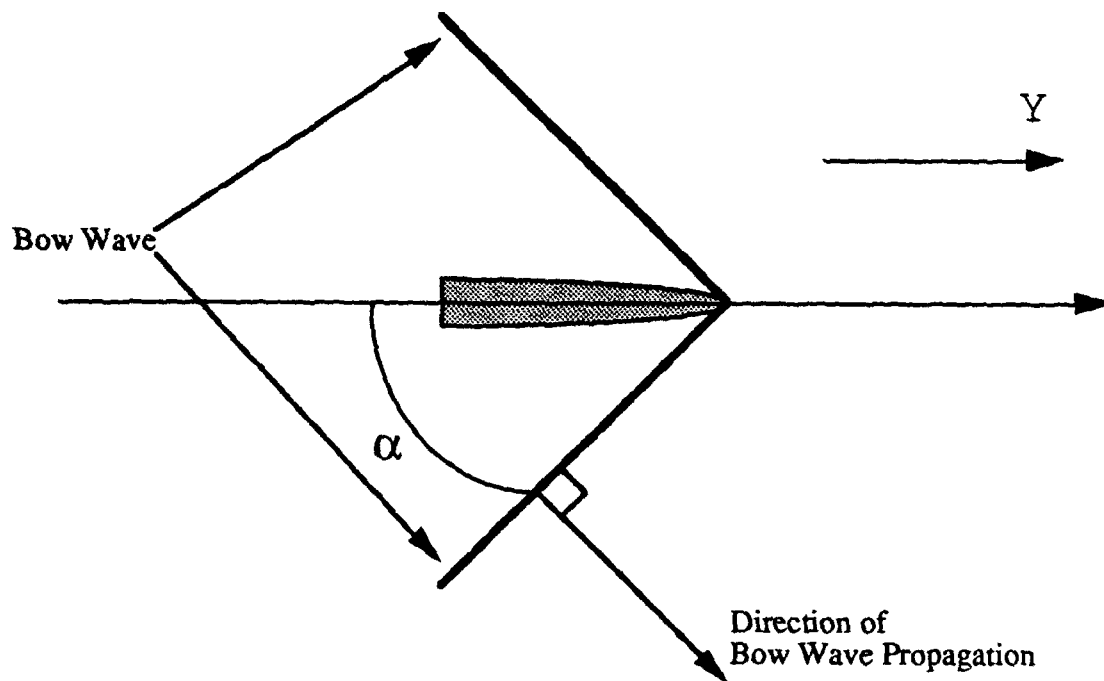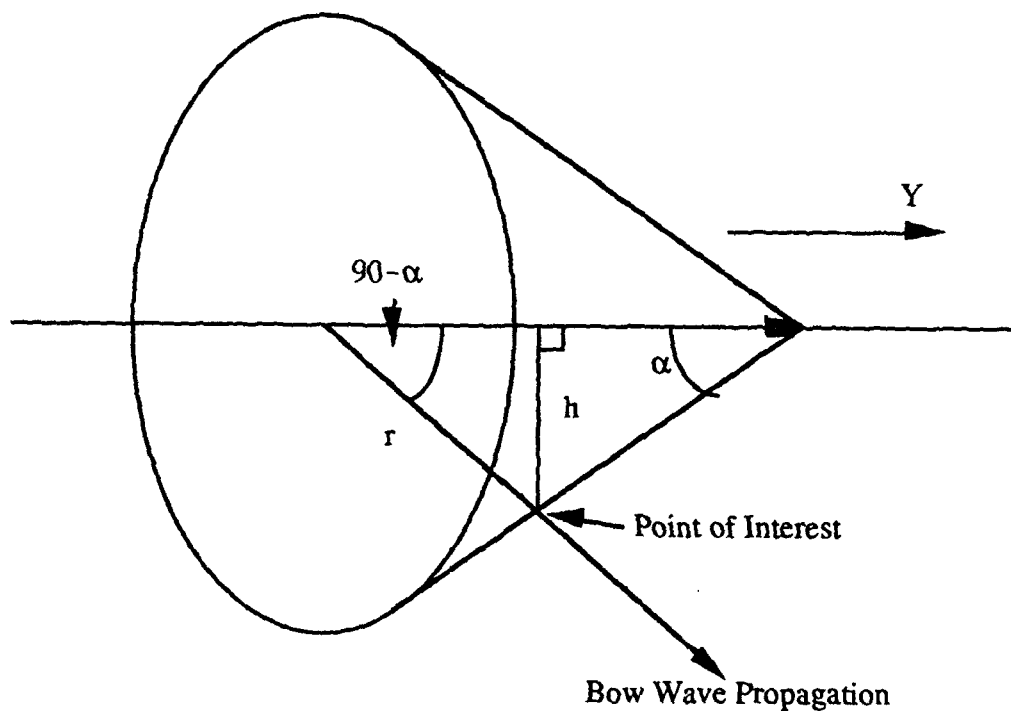
Figure 1. Geometry of Bow Wave.

Figure 2. Conical Spreading Pattern of Bow Wave.

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3 DATA COLLECTION

Test Site

These tests were performed at an open, flat test field in an isolated area of Aberdeen Proving Ground. The site was centered in a large, grassy field.

Gun handlers stood on top of a pickup truck and fired M16 rifles into a sand target 300 m down range. Both muffled and unmuffled guns were used. The mufflers were cylindrical and were screwed onto the barrel of the gun. Testing was performed over a 2-day period. The first day began with testing in the afternoon. All of the testing on day 1 was done with muffled guns. On day 2, bare muzzle guns were used for half of the tests and muffled guns for the other half.

In theory, a muzzled shot should contain only the bow wave portion of the sound, which would allow comparison of a gunshot's total sound generation to a bow wave with no further data manipulation. In practice, the data needed further analysis. Each round of testing began with several test shots to verify equipment setup. After several test shots, the remaining shots were fired in groups of 10 with 3 to 5 seconds between each round. The 10-shot groups alternated between muffled and unmuffled. Calibration tones were recorded at the beginning of each testing session using 92 dB acoustic calibrators.

The test equipment and site was designed to record data in which the muzzle blast and bow wave are distinguishable from each other. The general relationship between the two different wave propagation patterns (Figure 3) shows that the muzzle blast, as discussed earlier, propagates uniformly in a spherical pattern. Therefore, assuming uniform source directivity and equivalent paths of propagation from the source to each microphone, no special arrangement of the microphones is needed to properly monitor the decay of the muzzle blast. However, the bow wave is propagating linearly, as discussed previously. Therefore, to accurately monitor the decay of the bow wave, the microphones need to be arranged along the path of propagation of any given segment of the bow wave. That is, they must be located so that the portion of the bow wave that crosses the first microphone travels directly across all other microphones. In this test, this condition corresponds to locating the microphones on a ray intersecting the line of fire at an angle of $(90-\alpha)$.

To accomplish this arrangement, the testing range was designed with eight microphone stations located on a ray in the expected direction of bow wave propagation, with the origin of the ray 150 m down range from the point of fire, midway between the firing point and the target (Figure 4). The microphones were located at 25, 50, 75, 100, 150, 300, 500, and 750 m from the line of fire and thus the origin of the bow wave, and are 162, 176, 193, 211, 251, 386, 577, and 822 m from the point of fire, respectively. The geometry of the test setup demonstrates that the muzzle blast must travel farther than its associated bow wave to reach each microphone station. Since the portion of the bow wave to be monitored is that which is created 150 m down range from the point of fire, and the bullet speed is supersonic, there will be a delay between the arrival of the bow wave and the muzzle blast. This delay decreases as the stations get further away, and the difference in path length from the source to microphone decreases. This delay allows differentiation between the muzzle blast and bow wave.

Data Measurement

The data collection stations for this test were designed to monitor and record measurements during the test as well as record the entire test for any additional analysis required later. Each microphone station, shown in Figure 5, included a B&K 4921 microphone with external 12-volt battery, a USACERL Model 380 Noise Monitoring System, a modified Sony pulse code modulator with a Panasonic VHS video recorder, and an NEC Starlet computer. The Model 380 Noise Monitors measured A- and C-weighted sound exposure levels while the flat-weighted signal was recorded on the tape for later analysis. The first
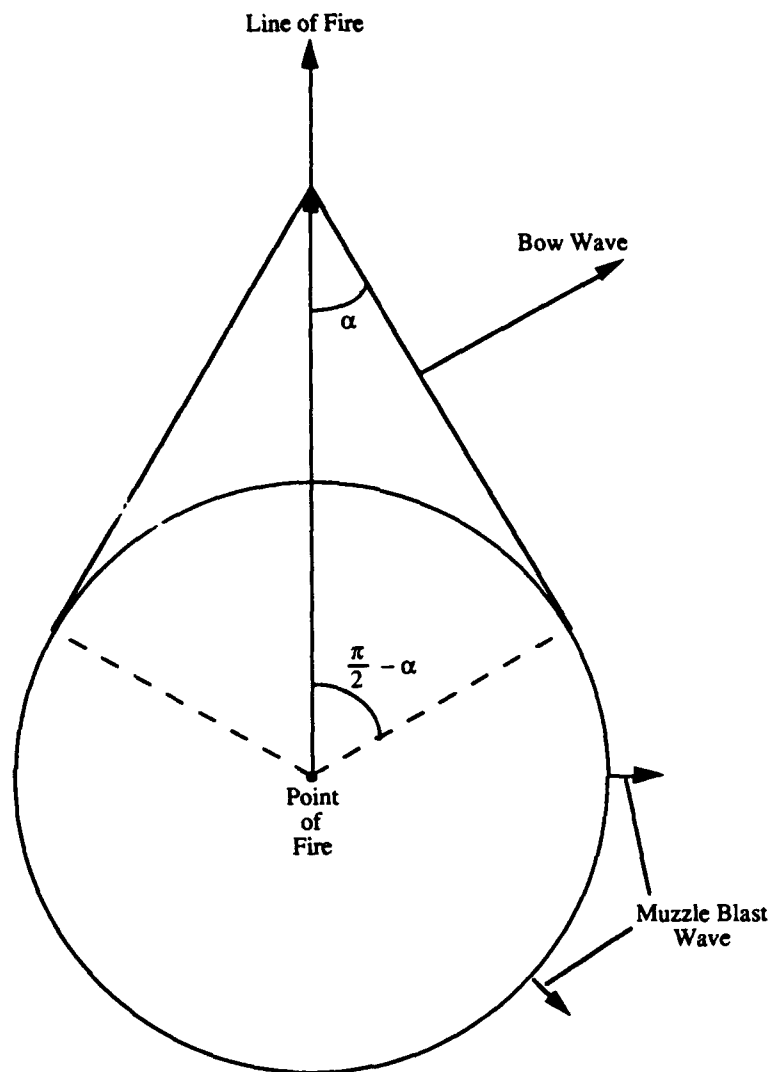
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Figure 3. Relationship of Muzzle Blast and Bow Wave Propagation Patterns.

five stations were connected by cable to the instrument van parked near the firing station. The data from these stations were monitored, recorded, and printed with instruments in the van. The outer four stations were manned stations. These stations were manually triggered, with the instruments set to pretrigger by 2 seconds. This allowed the people manning the stations to listen for a shot and then press the trigger button. After triggering, the monitors then calculated the necessary information from the data from the previous 2 seconds. The people recorded the levels from the monitors on data sheets for each shot. The VHS recorders were located at the microphone site and were running continuously throughout the test. The video channel was used with a pulse code modulator to record the output of the microphone while the audio channels were used for test narration.
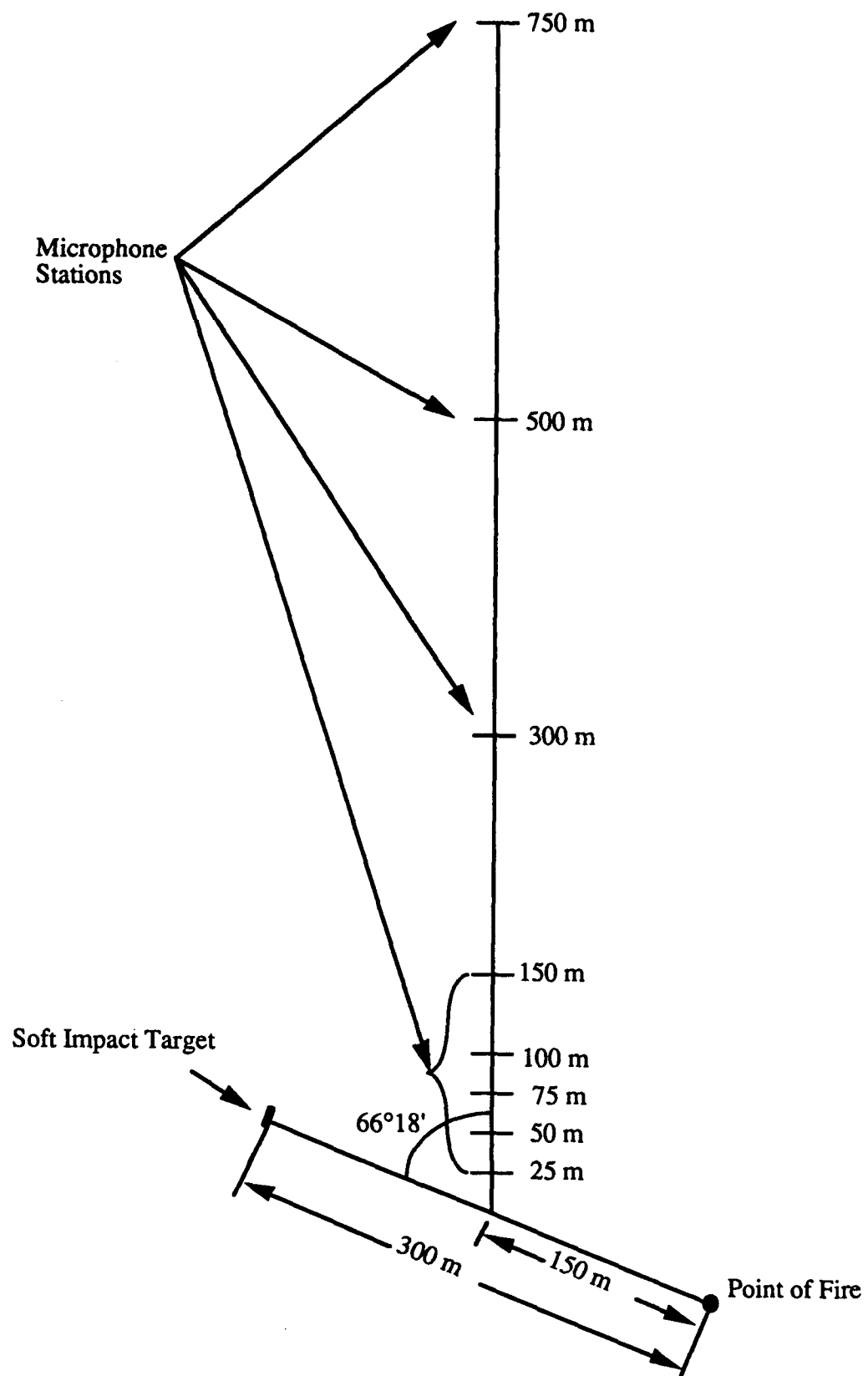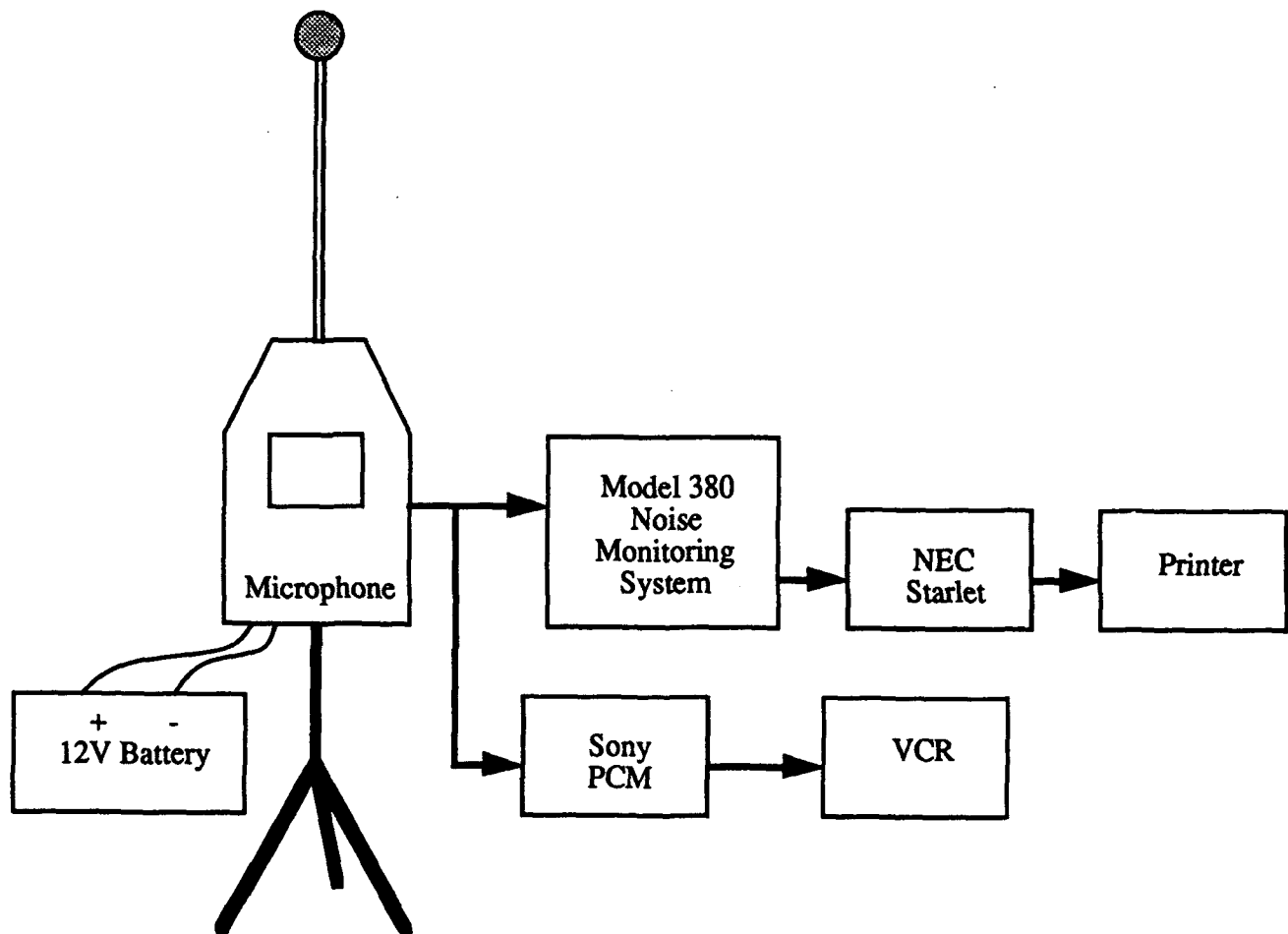
Figure 4. Overall Test Site Layout.

Figure 5. Microphone Station Setup.

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4   DATA ANALYSIS

Data Reduction

The tests were designed to:

1. Identify and quantify the two acoustic components of a gun shot, and

2. Study how the different components decay over distance and affect the overall SEL.

The data recorded digitally on VHS tape was first played back through a DATA6000 waveform analyzer and a sample was taken. The data was sampled at 50 microseconds with a total of 8192 points, leading to a sample of approximately 400 milliseconds. A sample bow wave and a sample muzzle blast from the 25-m station are shown in Figures 6 and 7, respectively. Figure 7 includes trailing oscillations for the bow wave passage. These appear as a "high frequency" wave added to the muzzle blast.

Each shot was analyzed in three ways. First, to isolate the muzzle blast, a time window containing the bow wave was set to zero and the muzzle blast remained unchanged. Then, an FFT (with no windowing) was performed using a DATA6000 computing oscilloscope. This analysis produced a narrow band graph of energy versus frequency. For each shot, the data developed by the FFT contained 4096 spectral lines. This type of analysis results in a resolution of 2.44 hertz (Hz) per line and a range from 2.44 Hz to 10 kHz. (These frequency data were saved as an ASCII file for further analysis.) Second, the original waveform was recalled from memory, and a similar procedure was performed to eliminate the muzzle blast portion, leaving only the bow wave. Third, FFT data were calculated for the entire shot, with both components present.

For each of the three analyses, the narrow band energy data in the ASCII file was summed into approximate one-third octave bands. Frequencies below 20 Hz had few data points per band and were discarded because of lack of resolution. The energy in the one-third octave bands was used to calculate the flat- and A-weighted SEL. Fifteen to 20 shots were analyzed and the energy in each band was averaged to obtain an average energy at each station. This average was then used to compute the average broad-band SEL of each component. The data recorded from the 750-m station was below the noise floor of the instruments and could not be extracted and analyzed further. Future data analysis will deal only with the first seven stations. The spectral plots of the bow wave and muzzle blast, for all stations, are shown in Appendixes A and B, respectively.

Frequency Analysis

The one-third octave analysis of the gun shots showed that the bow wave is centered around the 4 kHz band. The muzzle blast contains much lower frequency energy, with the flat weighted data centered around 200 Hz and the A-weighted data centered around 250 Hz. Because of the large difference in the main components of spectral energy between the bow wave and the muzzle blast, A-weighting the signal has a very large effect. An A-weighting filter attenuates the muzzle blast fundamental frequency by about 13 dB while it increases the bow wave by about 1 dB. Thus the A-weighting significantly affects comparison of the bow wave and muzzle blast. Both flat and A-weighted data are presented as appropriate; however, only A-weighted data are used for comparison.

Comparative Analysis

The different components must to be compared to determine rates of decay and relative sound level over distance. Figure 8 shows the levels of the bow wave and muzzle blast across distance. It is
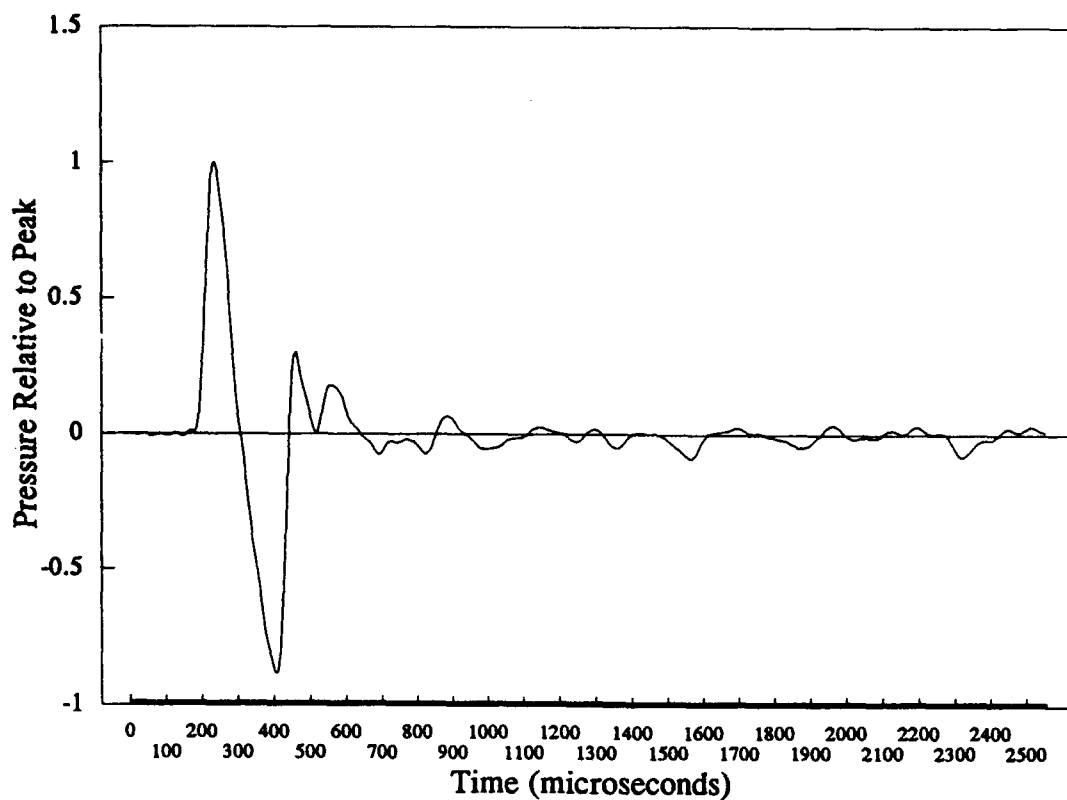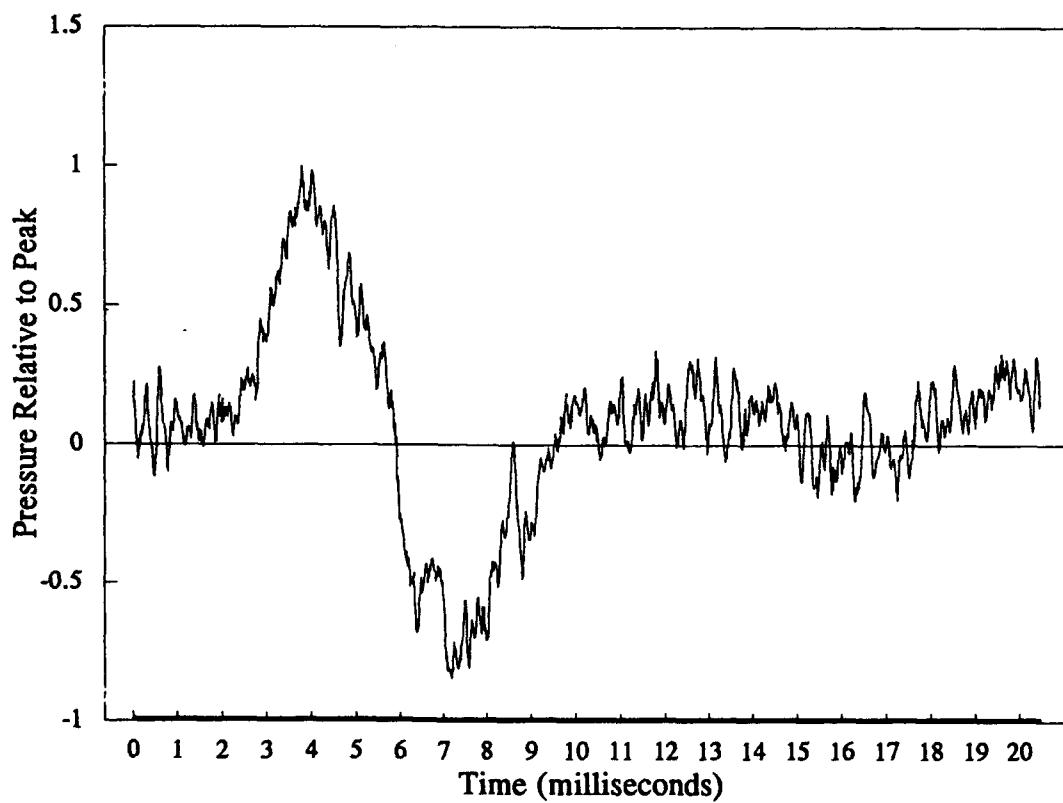
Figure 6. Sample Bow Wave From 25-m Station.

Figure 7. Sample Muzzle Blast From 25-m Station.

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important to note that the distance along which the levels are displayed is the distance from the line of fire to the microphone station. This is the true distance the bow wave has traveled. This is not, however, the distance the muzzle blast has traveled. Figure 9 shows that the muzzle blast must travel distance X at an angle β from the line of fire while the bow wave must only travel distance Y from its source. Due to this geometry, the decay rate of the muzzle blast, along the line of observation, is not the true decay rate. The effect of the nonuniform source directivity also becomes increasingly important as the angle from the source increases. A model has been developed which includes the dominant factors affecting the levels of the two components as they decay.

The major factors to be considered in modeling these decaying components are: geometric spreading, air absorption, and, for the muzzle blast, source directivity. The air absorptions coefficients, for a standard day with temperature of 15 °C and 70 percent relative humidity, were taken into account for each one-third octave band. The muzzle blast was assumed to be decaying at -6 dB per doubling of distance and the bow wave at -3 dB per doubling of distance, purely due to geometric spreading.* When modeling the
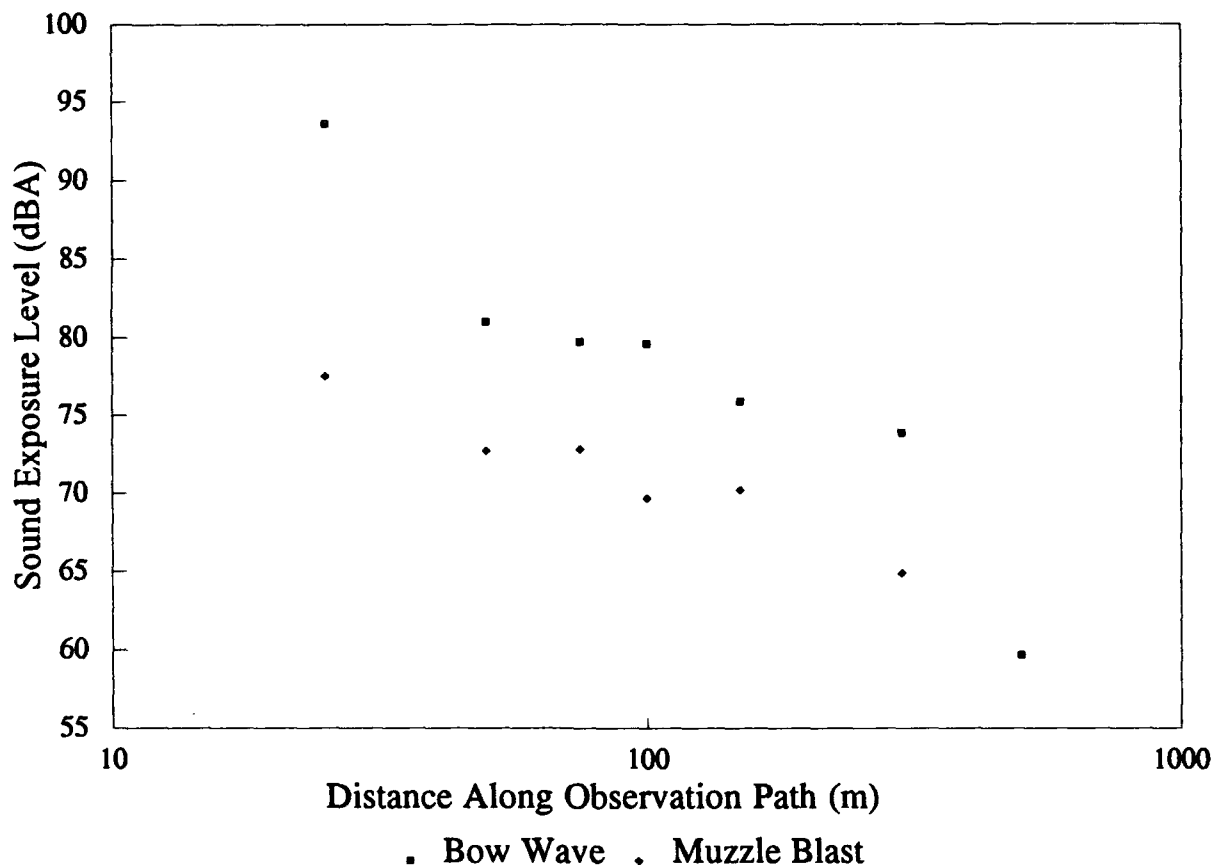

Figure 8. Muzzle Blast and Bow Wave ASEL vs. Distance Along Observation Path.

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* At some distance from the line of fire, the bow wave must also decay at 6 dB per doubling of distance. Since, in this case, the line of fire is 300 m, decay must be more like 6 dB per doubling of distance at 3000 m, 10 times the length of the line of fire. So Figure 10 is overly conservative. In the case of a 300-m firing range, one would expect the muzzle blast to predominate past about 3 to 5 km. However, were the line of fire 1 km long, then the muzzle blast could not predominate until about 10 km.
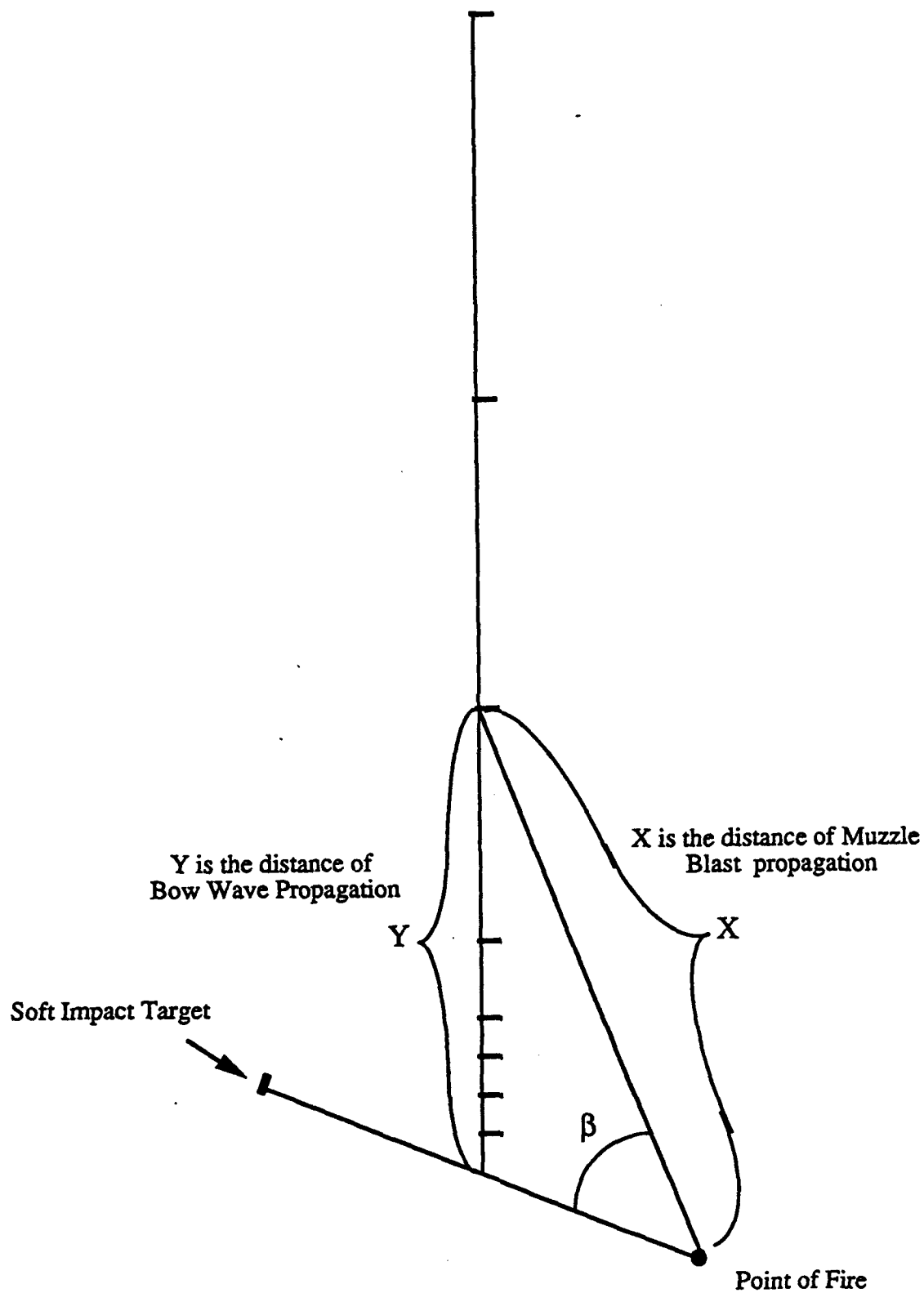
Y is the distance of
Bow Wave Propagation

X is the distance of Muzzle
Blast propagation

Y

X

Soft Impact Target

β

Point of Fire

Figure 9. Distances of Propagation for Muzzle Blast and Bow Wave.

muzzle blast, it is important to account for the nonuniform source directivity pattern. Pater (1985) defines the directivity pattern by:

$$\frac{D_o}{2} (-1 + \cos \beta \cos \gamma_o)$$ [Eq 3]

where:

β = azimuthal angle from the direction of fire
γ_o = gun elevation angle
D_o = 14.3 (for M16).

This equation indicates that the directivity can have a maximum effect of -14.3 dB. Since gun elevation angle was approximately zero, the directivity factor depends on only the azimuthal angle from the direction of fire. The model was fitted to this set of data using the 50-m station as a base point. That is, the 50-m spectral data exactly fits the model. The theoretical spectra were then calculated according to the model for distances both smaller and larger than 50 m. The spectral data was then summed to give theoretical ASEL versus distance. The levels determined by the model and the actual data are shown together in Figure 10; the model fits the data well. The level of the model is consistently low by about 2 to 3 dB for both components. It seems probable that this is a result of the 50-m data point being low in comparison with other stations. If the model were to consider a different data point as the base, or were raised to be a "best fit" curve, it would approximate the data very well. This indicates that the model accurately reflects the important factors affecting the propagation of both components.
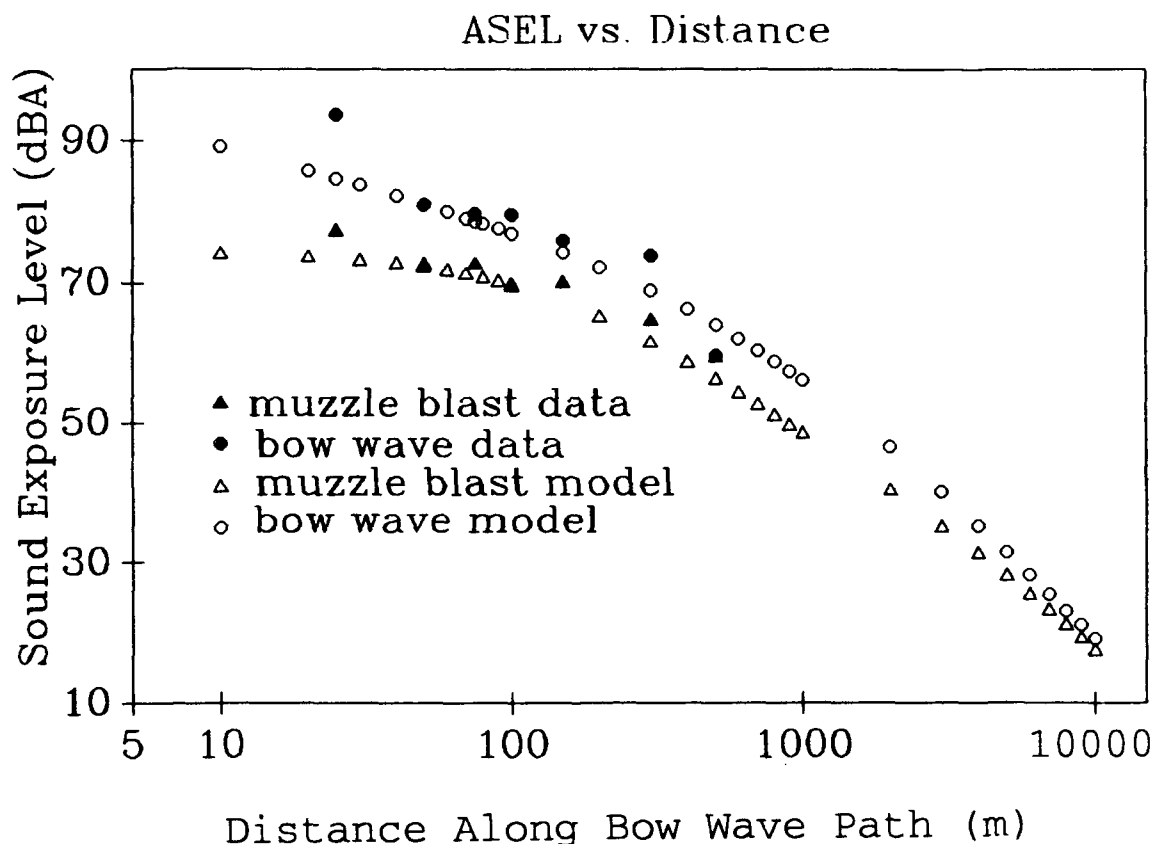

Figure 10. Model vs. Experimental Data (Muzzle Blast and Bow Wave).

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5 SUMMARY

This research showed the spectral data gathered from the small arms fire and identified the bow wave and muzzle blast as the important components. The decay rates of the different components, as observed along the microphone array, were also shown. Considering the geometry of the test setup, the bow wave is the dominant component at all test locations. Along lines that interest the line of fire at angles greater or lesser than the one specifically tested in this research, the bow wave will not be at a maximum. Therefore, along these lines the muzzle blast predominates a distances less than 10,000 m. For example, directly in front of the gun the muzzle blast has a directivity factor of O dB and it will predominate within a few hundred meters. The muzzle blast will always predominate in areas along lines that interest the line of fire at angles greater than 90 minus the mach angle (α). But the bow wave must be considered if communities are within 10,000 m (10 km) of the firing range and lie along lines that interest the line of fire at an angle less than 90-α.

REFERENCES

Thompson, Andrew A., *The Acoustic Environment Predicted from the Firing of a 175mm Gun*, BRL Memorandum Report No. 1910 (U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD).

Pater, L.L., *Gun Blast Far Field Peak Overpressure Contours*, NSWC TR 79-442 (Combat Systems Department, Naval Surface Weapons Center, 1981).

Pierce, Allan D., *Acoustics An Introduction to its Physical Principles and Applications* (Acoustical Society of America, Woodbury, New York, 1989).

APPENDIX A: Plots of One-Third Octave Spectra of Bow Wave
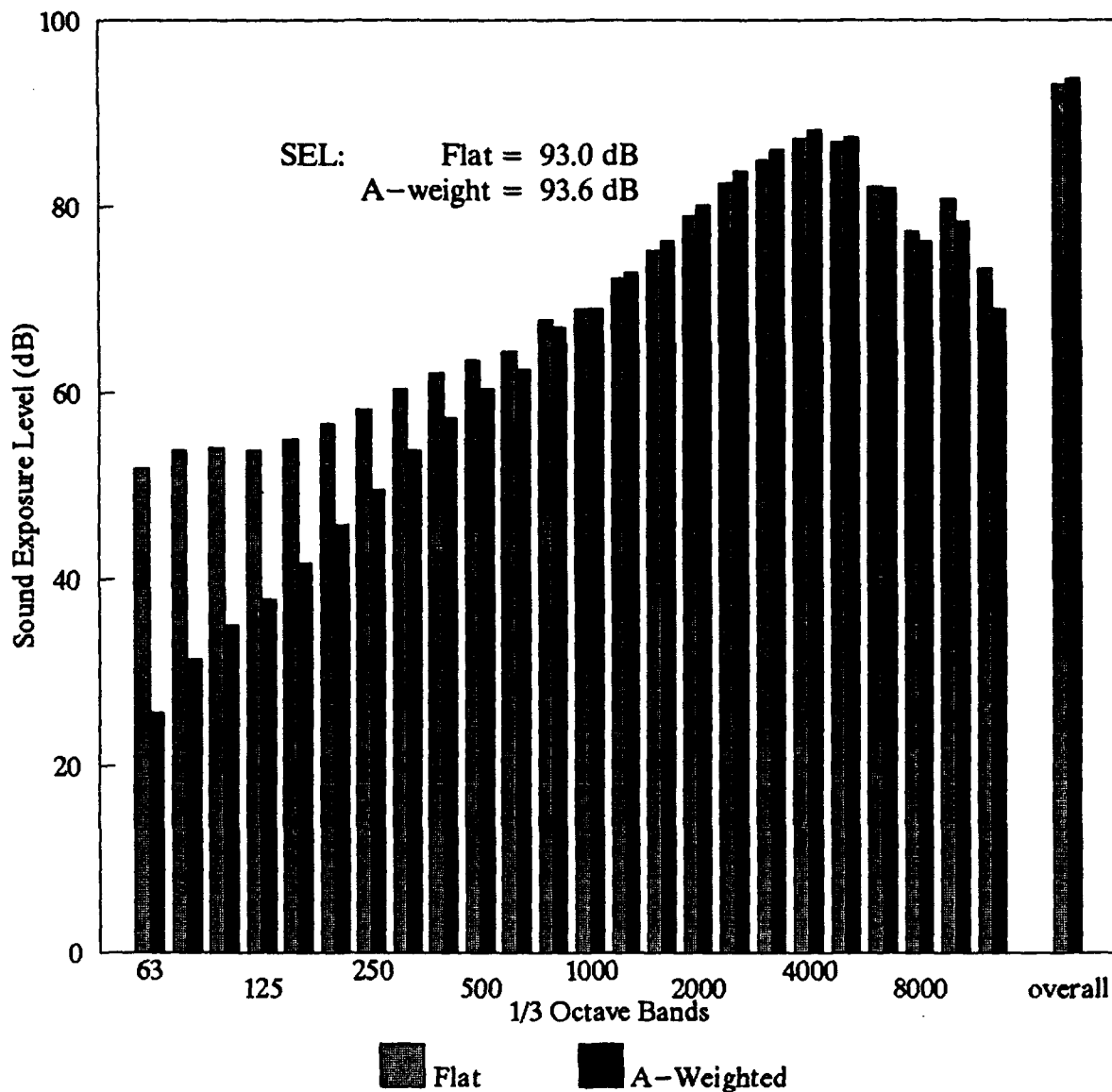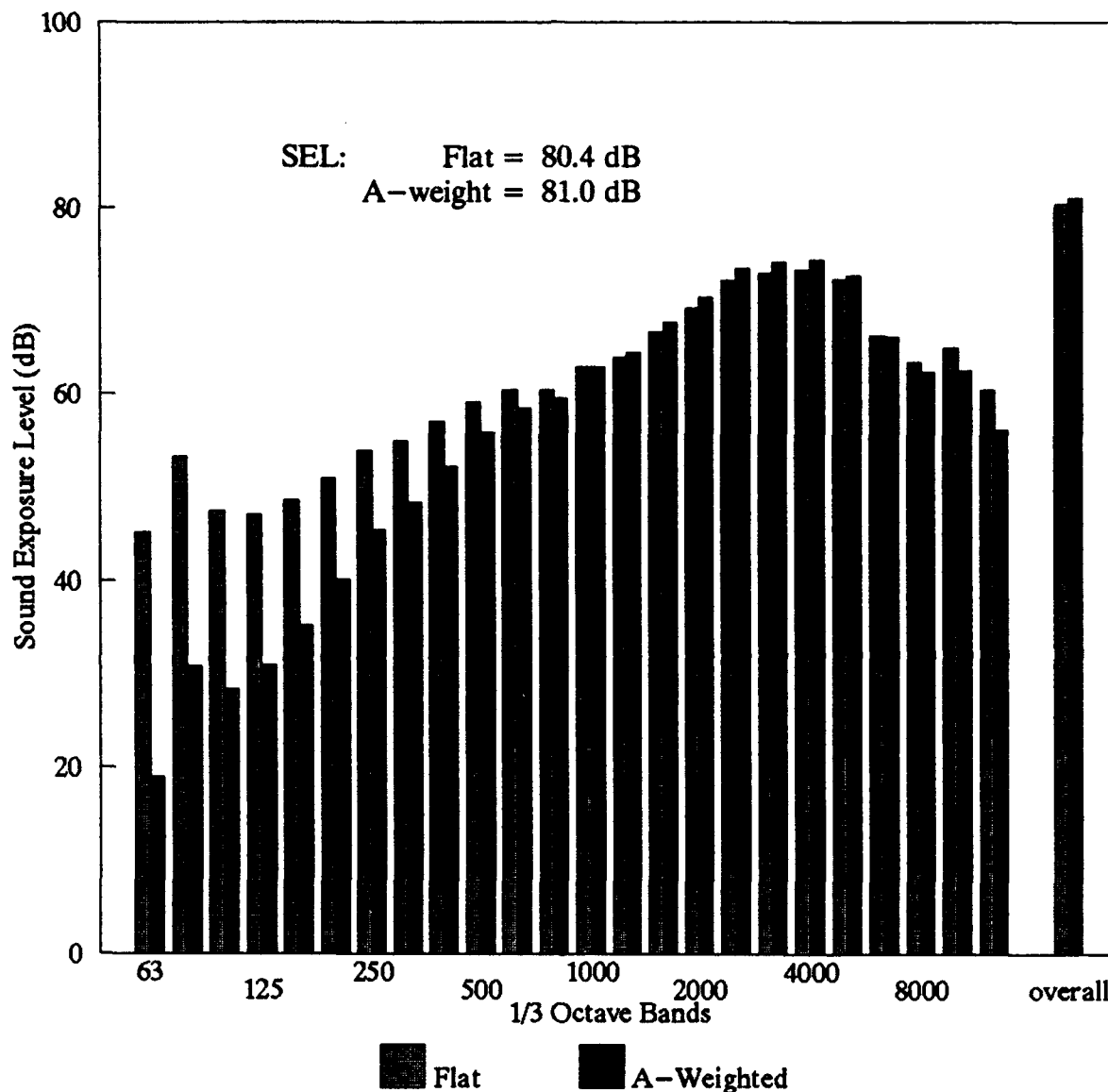

Figure A1. Bow Wave Energy Spectrum 25 m From the Line of Fire.

The measurement site was 162 m from the muzzle, forming an angle of 8 degrees with the line of fire. As shown in Figure 9, the measurement site was along a line eminating from the center of the line of fire and perpendicular to the mach angle. The distance along this line, from the line of fire was 25 m. Data below the 63 Hz one-third octave band were deleted due to wind noise.
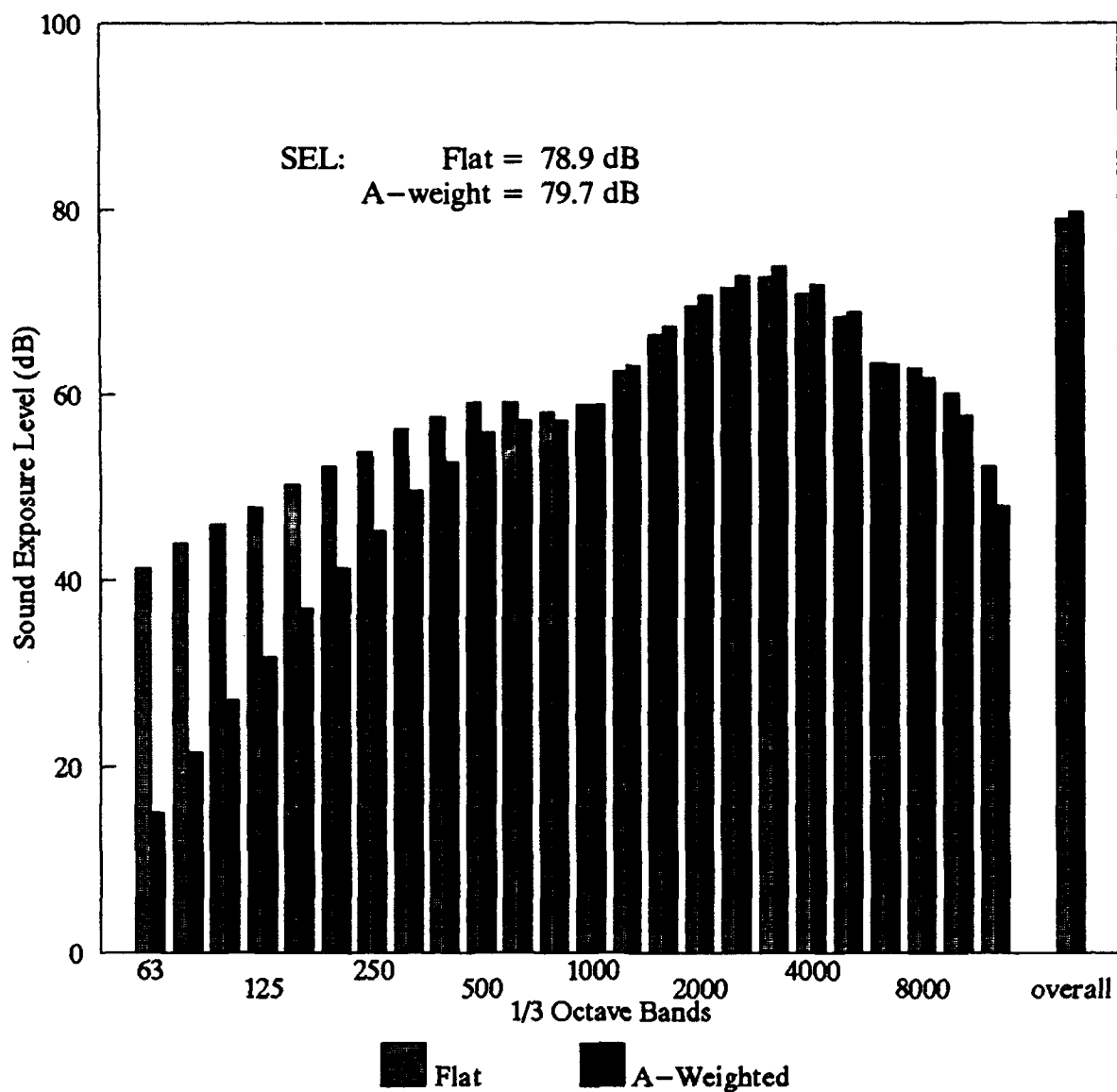
SEL: Flat = 80.4 dB
      A−weight = 81.0 dB

Figure A2. Bow Wave Energy Spectrum 50 m From the Line of Fire.

The measurement site was 176 m from the muzzle, forming an angle of 15 degrees with the line of fire. As shown in Figure 9, the measurement site was along a line eminating from the center of the line of fire and perpendicular to the mach angle. The distance along this line, from the line of fire was 50 m. Data below the 63 Hz one-third octave band were deleted due to wind noise.
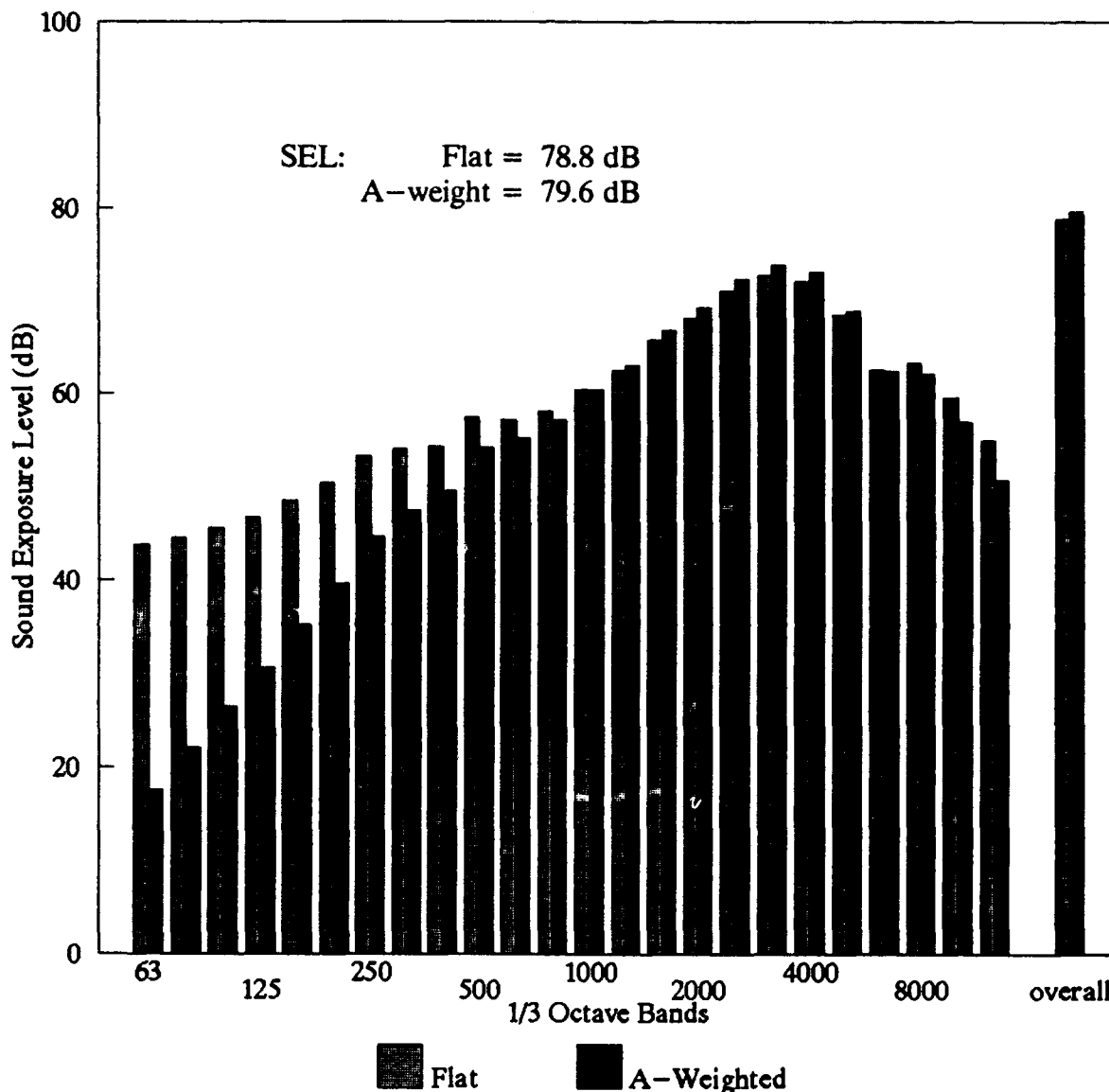
Figure A3. Bow Wave Energy Spectrum 75 m From the Line of Fire.

The measurement site was 193 m from the muzzle, forming an angle of 21 degrees with the line of fire. As shown in Figure 9, the measurement site was along a line eminating from the center of the line of fire and perpendicular to the mach angle. The distance along this line, from the line of fire was 75 m. Data below the 63 Hz one-third octave band were deleted due to wind noise.
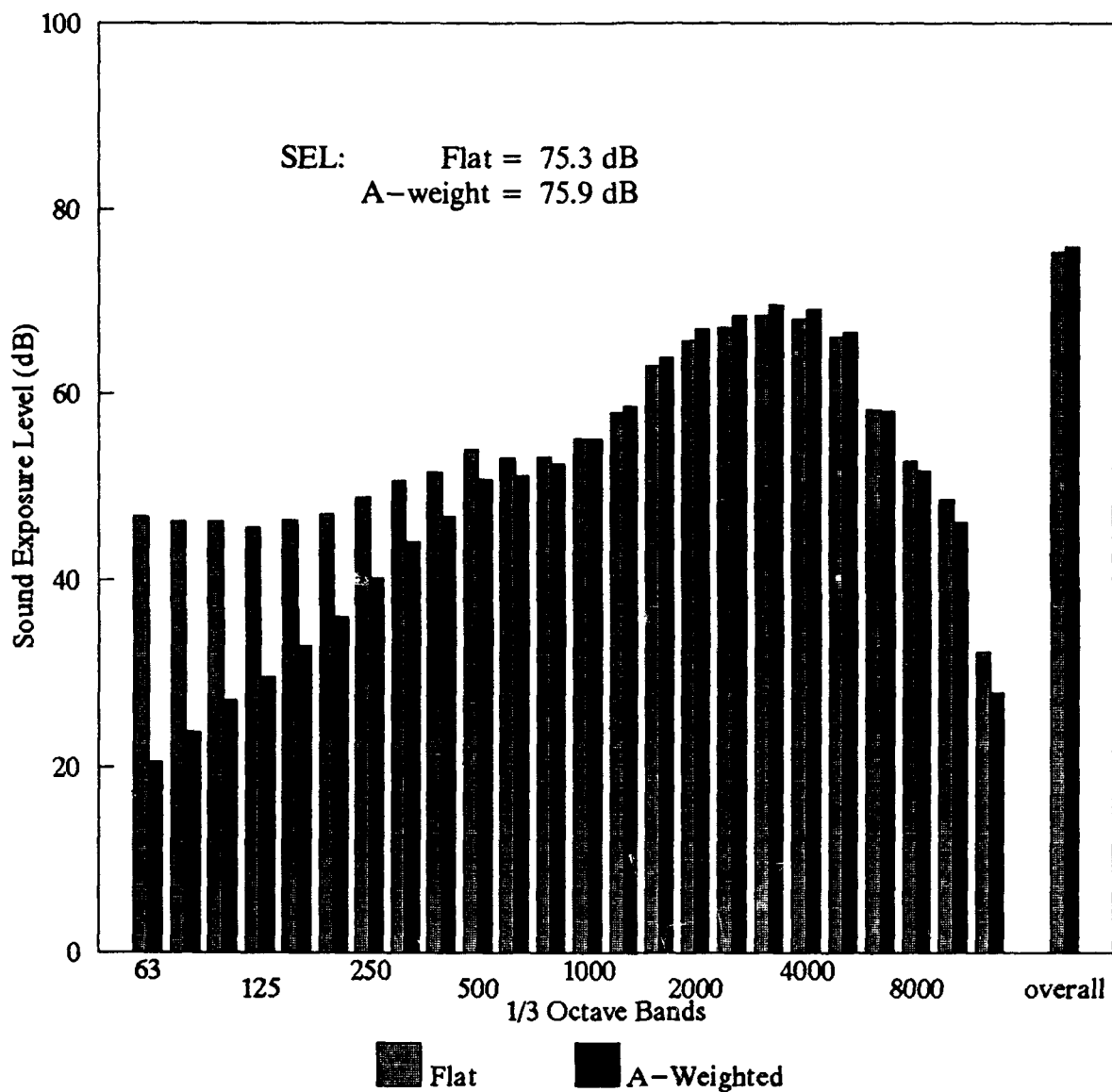
Figure A4. Bow Wave Energy Spectrum 100 m From the Line of Fire.

The measurement site was 211 m from the muzzle, forming an angle of 26 degrees with the line of fire. As shown in Figure 9, the measurement site was along a line eminating from the center of the line of fire and perpendicular to the mach angle. The distance along this line, from the line of fire was 100 m. Data below the 63 Hz one-third octave band were deleted due to wind noise.
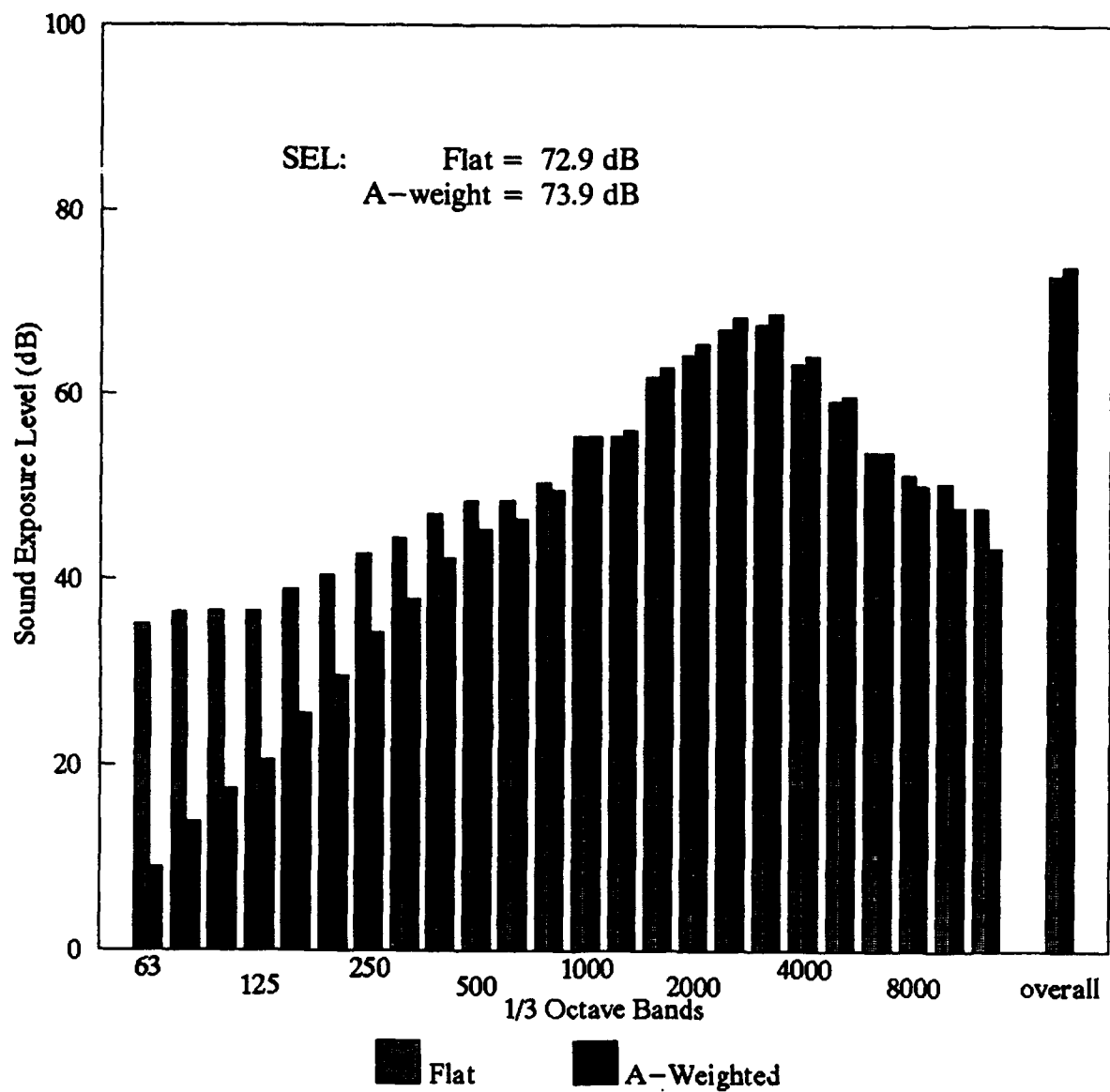
Figure A5. Bow Wave Energy Spectrum 150 m From the Line of Fire.

The measurement site was 251 m from the muzzle, forming an angle of 33 degrees with the line of fire. As shown in Figure 9, the measurement site was along a line eminating from the center of the line of fire and perpendicular to the mach angle. The distance along this line, from the line of fire was 150 m. Data below the 63 Hz one-third octave band were deleted due to wind noise.
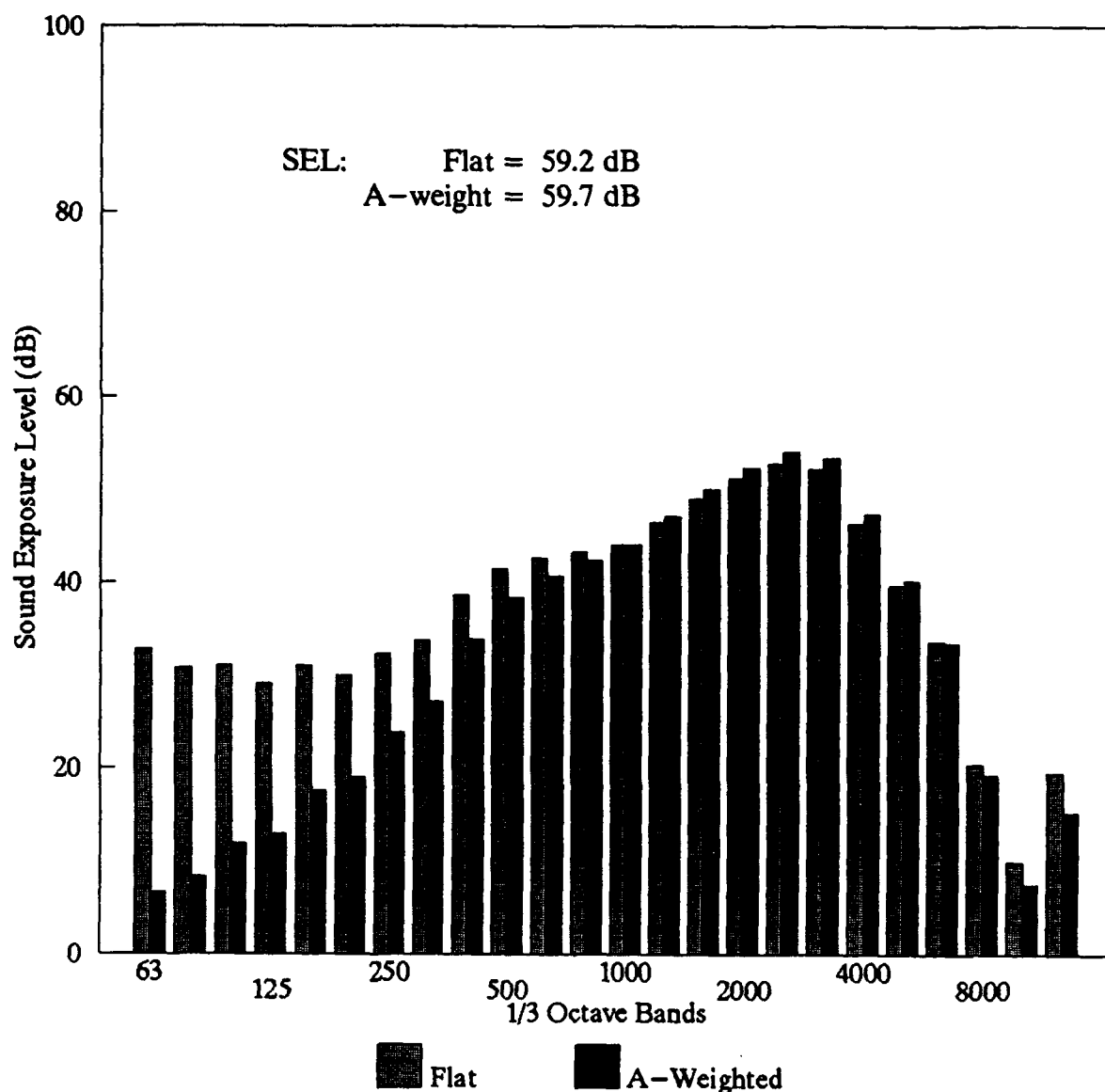
Figure A6. Bow Wave Energy Spectrum 300 m From the Line of Fire.

The measurement site was 386 m from the muzzle, forming an angle of 45 degrees with the line of fire. As shown in Figure 9, the measurement site was along a line eminating from the center of the line of fire and perpendicular to the mach angle. The distance along this line, from the line of fire was 300 m. Data below the 63 Hz one-third octave band were deleted due to wind noise.

Figure A7. Bow Wave Energy Spectrum 500 m From the Line of Fire.

The measurement site was 577 m from the muzzle, forming an angle of 53 degrees with the line of fire. As shown in Figure 9, the measurement site was along a line eminating from the center of the line of fire and perpendicular to the mach angle. The distance along this line, from the line of fire was 500 m. Data below the 63 Hz one-third octave band were deleted due to wind noise.

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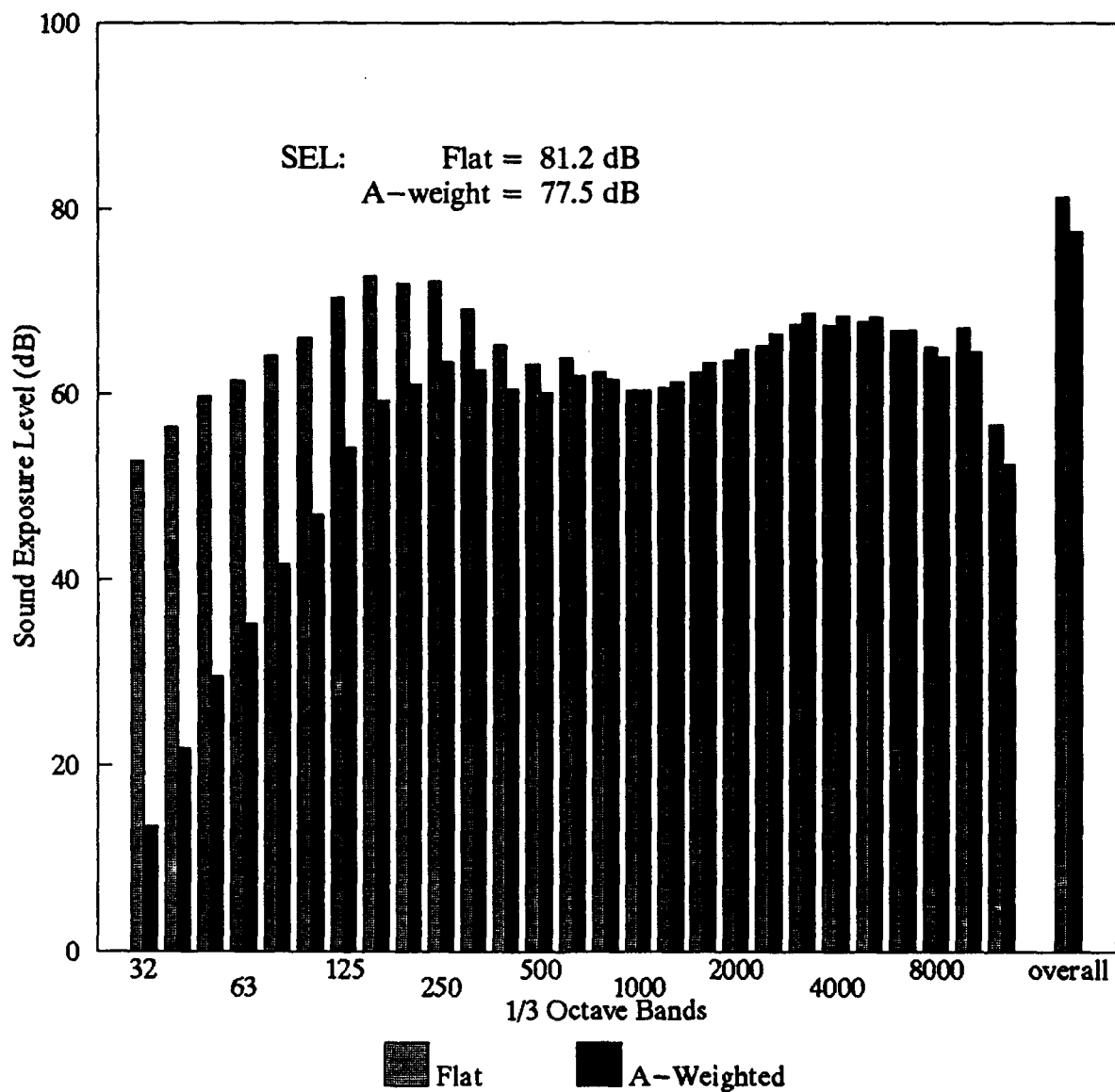SEL: Flat = 81.2 dB
      A-weight = 77.5 dB

Figure B1. Muzzle Blast Energy Spectrum 162 m From the Muzzle.

The measurement site was 162 m from the muzzle, forming an angle of 8 degrees with the line of fire. Data below the 32 Hz one-third octave band were deleted due to wind noise.
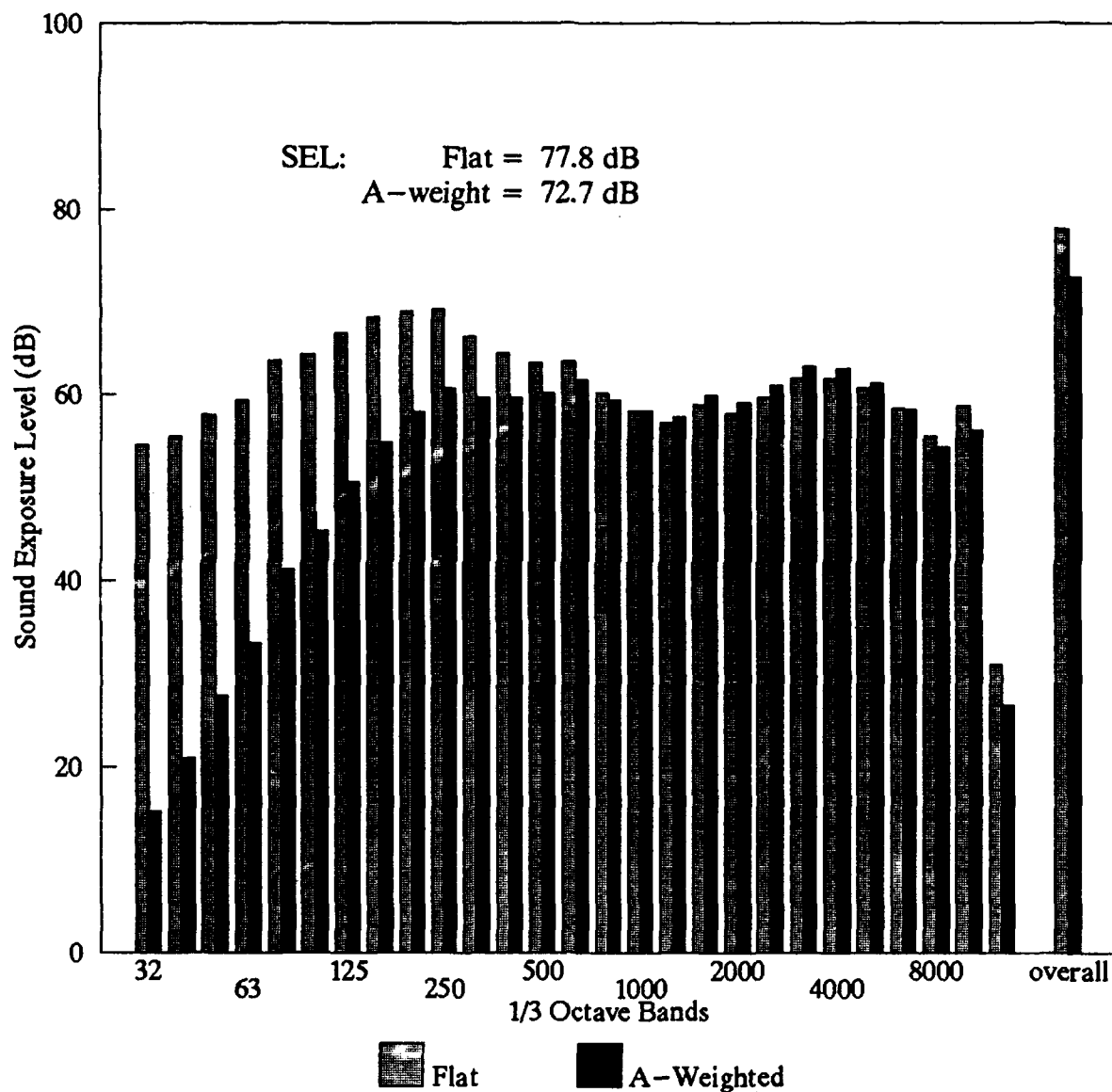
Figure B2. Muzzle Blast Energy Spectrum 176 m From the Muzzle.

The measurement site was 176 m from the muzzle, forming an angle of 15 degrees with the line of fire. Data below the 32 Hz one-third octave band were deleted due to wind noise.
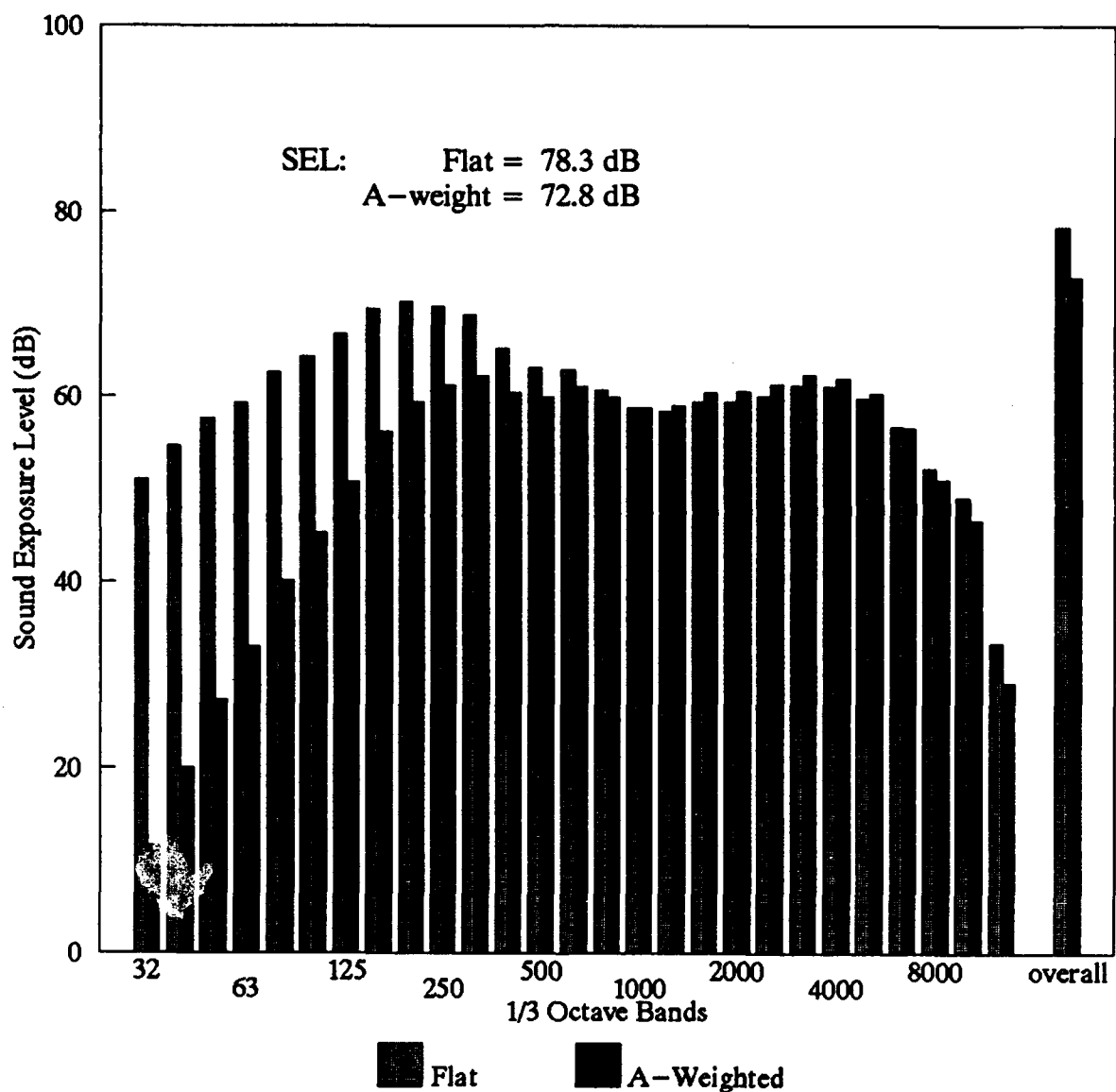
Figure B3. Muzzle Blast Energy Spectrum 193 m From the Muzzle.

The measurement site was 193 m from the muzzle, forming an angle of 21 degrees with the line of fire. Data below the 32 Hz one-third octave band were deleted due to wind noise.
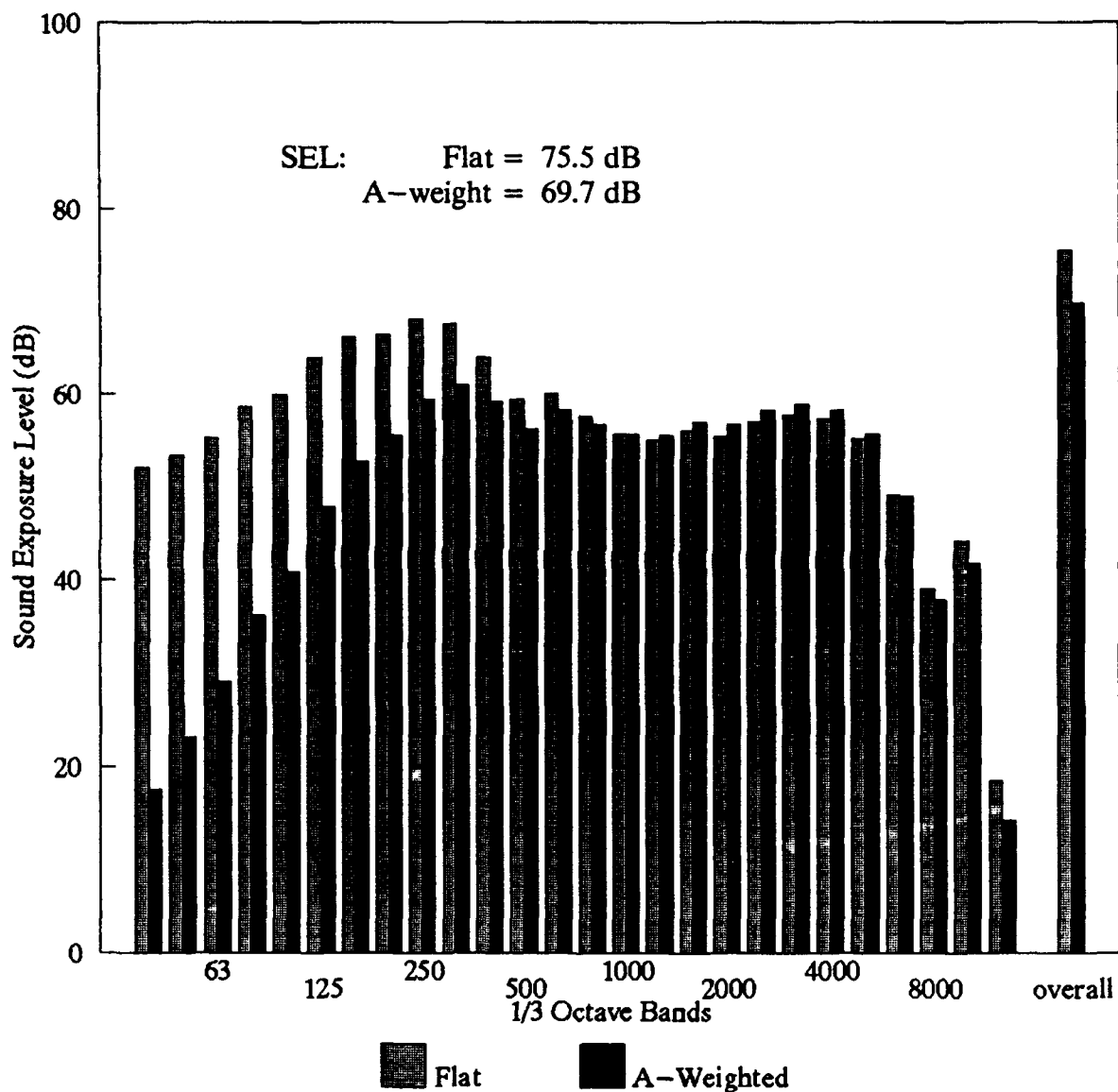
Figure B4. Muzzle Blast Energy Spectrum 211 m From the Muzzle.

The measurement site was 211 m from the muzzle, forming an angle of 26 degrees with the line of fire. Data below the 40 Hz one-third octave band were deleted due to wind noise.
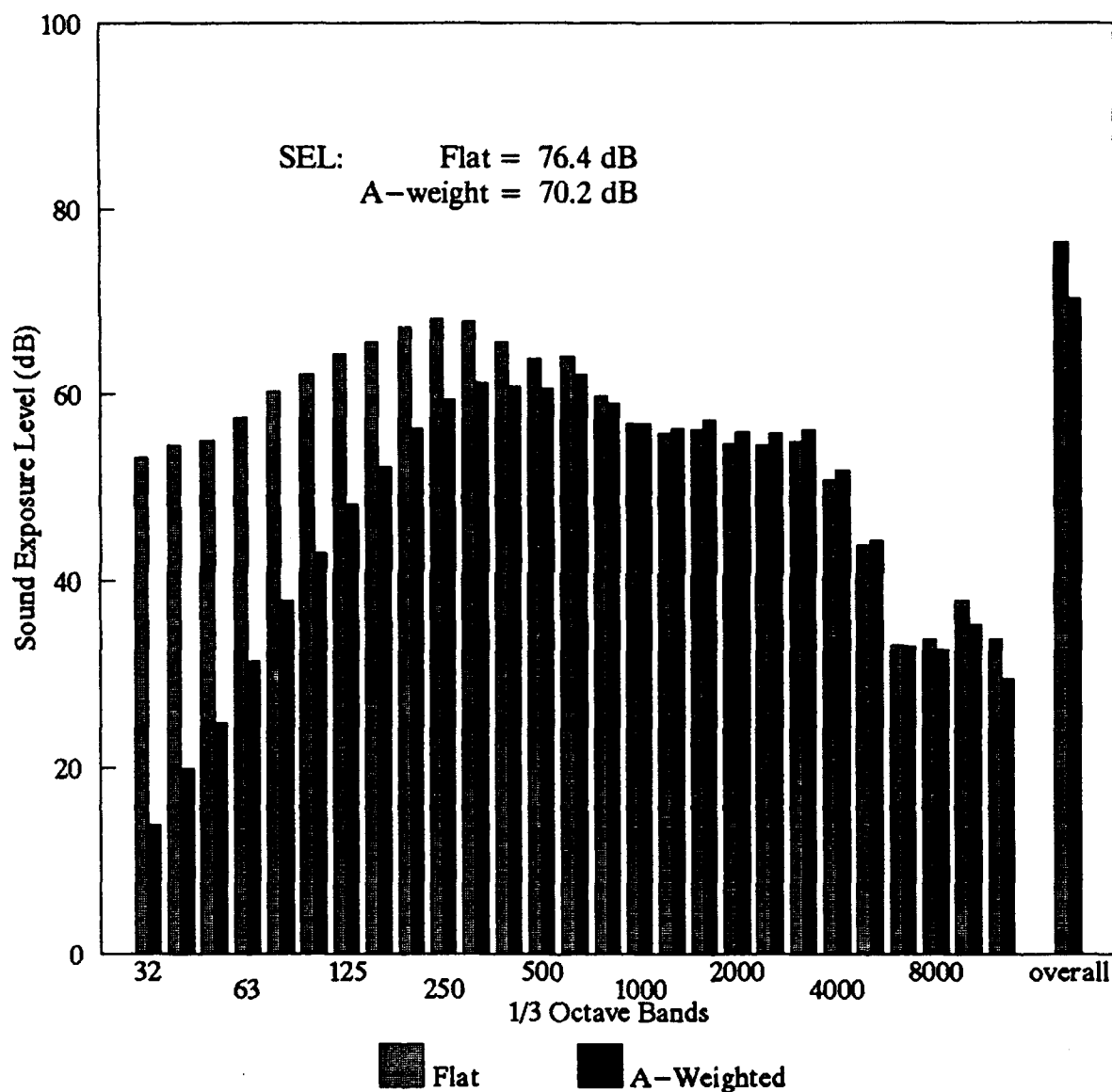
Figure B5. Muzzle Blast Energy Spectrum 251 m From the Muzzle.

The measurement site was 251 m from the muzzle, forming an angle of 33 degrees with the line of fire. Data below the 32 Hz one-third octave band were deleted due to wind noise.
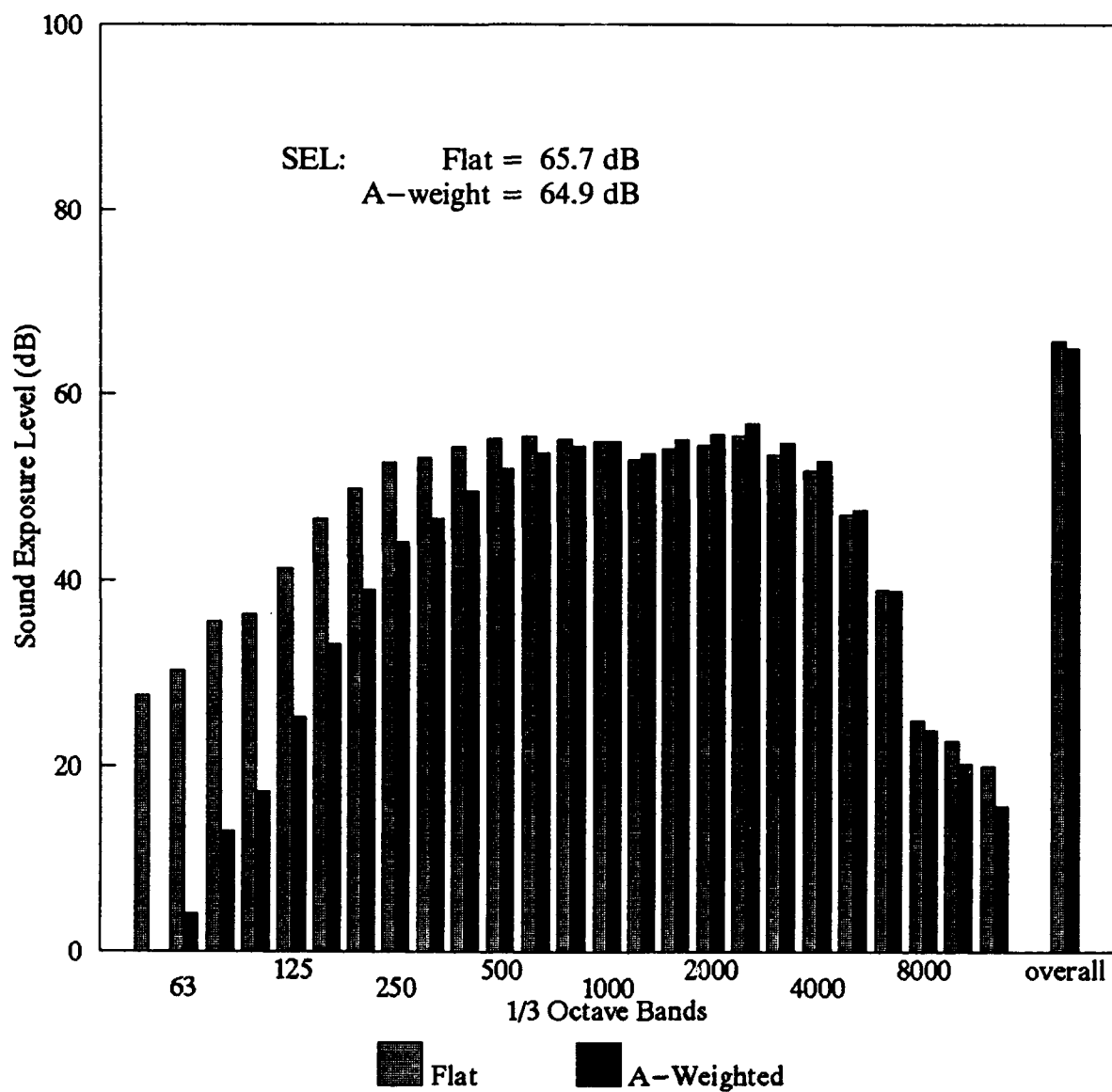
Figure B6. Muzzle Blast Energy Spectrum 386 m From the Muzzle.

The measurement site was 386 m from the muzzle, forming an angle of 45 degrees with the line of fire. Data below the 50 Hz one-third octave band were deleted due to wind noise.
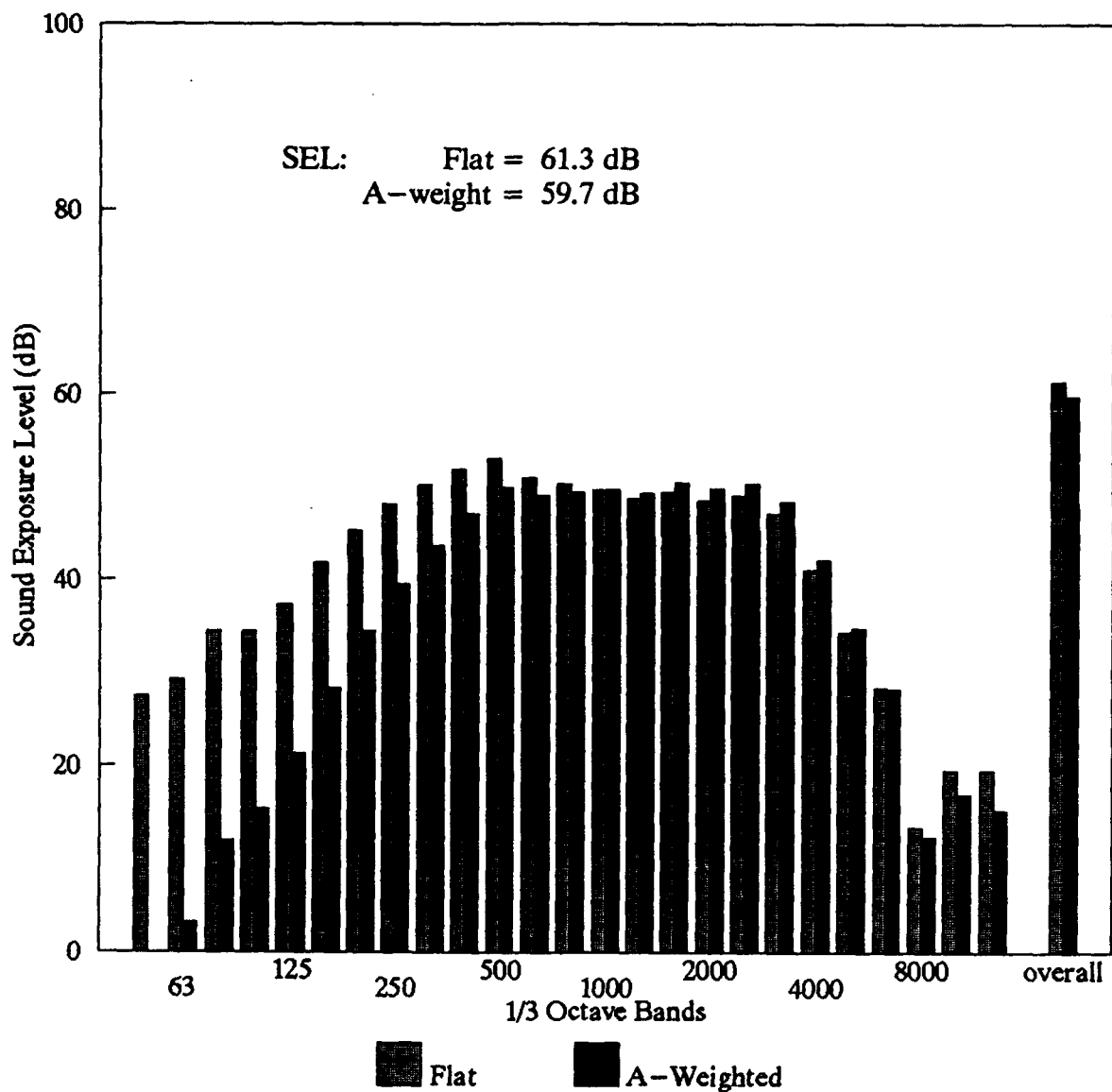
Figure B7. Muzzle Blast Energy Spectrum 577 m From the Muzzle.

The measurement site was 577 m from the muzzle, forming an angle of 53 degrees with the line of fire. Data below the 50 Hz one-third octave band were deleted due to wind noise.

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